Automated Verification of Mesoscale Forecasts Using Spatial Statistics

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Award Number: N00014-01-G-0460

LONG-TERM GOALS

The APL atmospheric sciences group is working to improve forecaster performance at Navy operational weather forecast detachments afloat and ashore. This work encompasses broad research and technology development in areas of visualization, human factors, human-machine interaction, and model and forecast verification with an emphasis on mesoscale ensembles and visualization of uncertainty. The verification effort's long-term goal is to develop an automated, objective verification technique for assessment of very high-resolution mesoscale predictions which accurately accounts for spatially or temporally misplaced features, false alarms and misses (Brown 2002).

OBJECTIVES

The overall objective of this effort is to develop a highly automated, rapid, object-oriented, mesoscale numerical weather prediction (NWP) verification tool for use by forecasters and model developers. The verification technique should consider distortion errors (phase/timing, rotation, and stretching) as well as the normal amplitude errors. It is intended to test the verification tool on the University of Washington Short Range Ensemble Forecast System (SREF) and with a version of the Navy COAMPS model implemented at APL.

APPROACH

Recently, a number of techniques from spatial statistics have shown promise in verification problems (Marzban and Sandgathe 2005; Harris and Foufoula-Georgiou 2005). Among them there exists one technique which not only allows for a novel verification method, but also addresses a central issue in our mesoscale verification technique (MVT) - the "box size" (or characteristic length scale as discussed in Hoffman et al 1995 and Nehrkorn et al 2003). The tool is the variogram and our proposal is to use the variogram to address the length-scale issue, both for verification and to address the 'feature' background error covariance.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2006**	2. REPORT TYPE	3. DATES COVERED **00-00-2006 to 00-00-2006**

4. TITLE AND SUBTITLE **Automated Verification of Mesoscale Forecasts Using Spatial Statistics**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Washington,Applied Physics Laboratory,1013 N.E. 40th St.,Seattle,WA,98105**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

A variogram is a diagram that displays the covariance (or correlation) between pair of points as a function of the distance (and direction) between them. In Spatial Statistics it is employed to quantify the covariance structure of a spatial field. The variogram can be employed for the following three purposes:

1) for verification purposes,

Like a power spectrum, a variogram quantifies the various scales present in a field. From an image-processing point of view, a variogram assesses the texture of an image. When applied to a forecast field and an observation/analysis field, it provides a means of comparing the two fields in terms of their texture, or the distribution of energy among the various scales. Harris and Foufoula-Georgiou (2005) were the first to propose variograms as a verification tool.

Various features of a variogram can be distilled (quantified) in order to allow automation of the verification procedure. Three such features which also have physical significance are the nugget, the sill, and the range. The nugget refers to the y-intercept of the variogram (or the model fit to it); the sill is the value along the y-axis at which the curve levels off, and the range is the corresponding value along the x-axis. The slope of the rising portion of the variogram can also be considered as another scalar verification measure.

2) to provide an objective assessment of the length scale to be used in MVT, which in turn, is employed for verification.

Through their implicit treatment of scales, variograms also provide an objective estimate of the characteristic length scale in a field. This length scale, in turn, is related to the "box size", a quantity in MVT that is often determined in an ad hoc or subjective manner (Hoffman et al 1995 and Nehrkorn et al 2003).

3) to provide an alternative estimate of the background error covariance.

The issue of characteristic length enters the estimation of background error covariance matrix ("**B**"). As such, variograms can also yield estimates of **B**, but in a way that is more conducive to a verification scheme based on variograms. Sen (1997) has shown the utility of this specific use of variograms.

WORK COMPLETED

New effort.

RESULTS

New effort.

IMPACT/APPLICATIONS

Verification systems need to be highly automated in order to rapidly assess large samples of cases; however, they must also be able to correctly evaluate the high frequency, high amplitude signals of mesoscale features. Unfortunately, traditional methods of verification have been shown not to work for mesoscale numerical weather prediction. Simple automated techniques incorrectly assess slight phase or displacement errors, causing smoothed, or ensemble mean forecasts to appear to perform better than a more detailed deterministic forecast, yet they contain less forecast content. Case studies, while more revealing, are too time consuming to assess the large number of cases required for subtle model biases

or differences arising from small changes in model algorithms. Mesoscale NWP forecast verification is a critical issue for US Navy operations. More NWP model outputs are becoming available from various sources and it is difficult for management and operational forecasters to choose the appropriate system for each forecast situation. The forecast verification tool will enable more accurate and meaningful evaluation of mesoscale numerical weather prediction systems, especially mesoscale ensemble systems, where large volumes of data are required for accurate assessment and where small prediction distortions or displacements cause significant misinterpretation of verification results. The tool is intended for use both by model developers and by forecasters for quick and more accurate model assessment. The forecaster tool will be implemented as an easy to use web tool.

RELATED PROJECTS

The University of Washington Multidisciplinary University Research Initiative (MURI) on Integration and Visualization of Multi-Source Information for Mesoscale Meteorology: Statistical and Cognitive Approaches to Visualizing Uncertainty. This project incorporates a number of verification techniques into a forecaster visualization tool and a prototype version of our mesoscale verification tool has been implemented here. The Environmental Visualization (EVIS) effort of the Knowledge Superiority FNC funded by ONR has reviewed the MVT and is planning to test it as a potential user application.

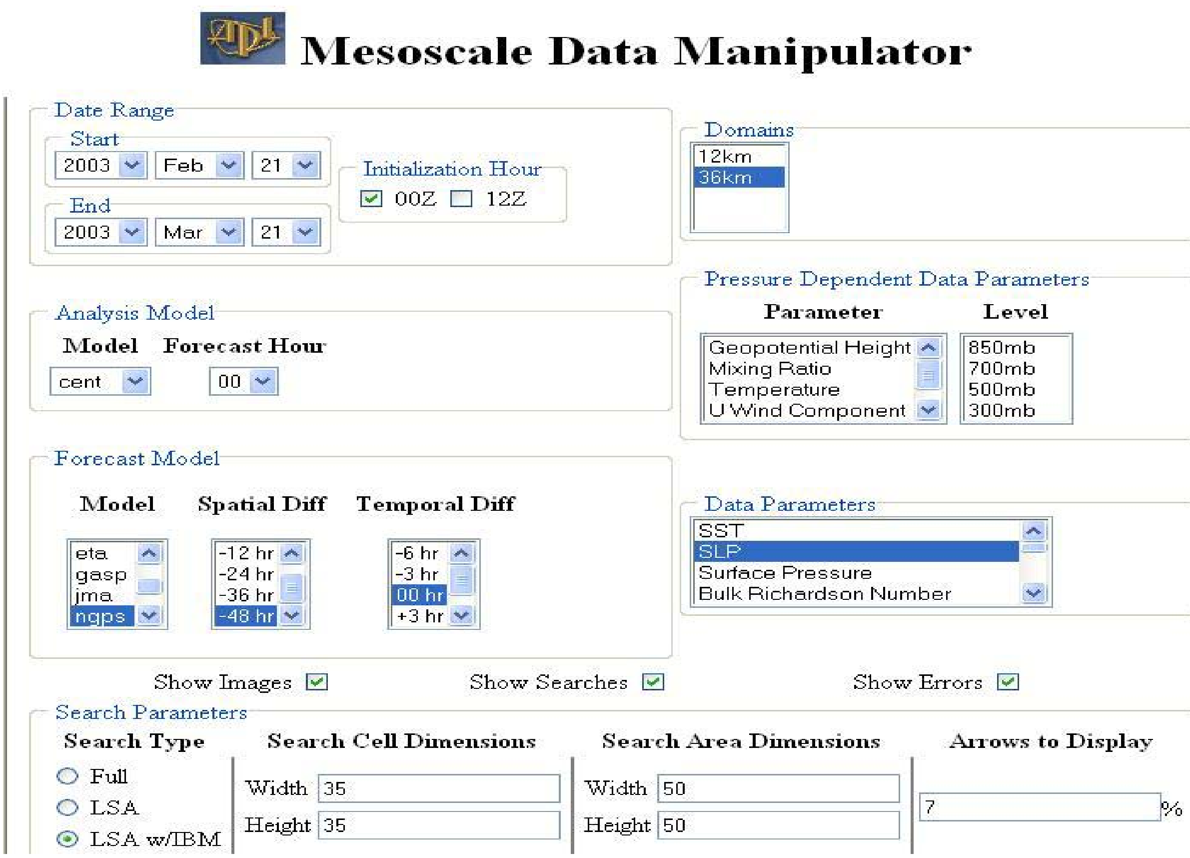

Figure 1. Automated Mesoscale Verification Tool GUI
[Automated Mesoscale Verification Tool (AMVT) Graphical User Interface displaying model and parameter selection for web-based submission of large and/or complex verification of multiple models or multi-member ensembles.]

A cluster analysis technique (Marzban and Sandgathe, 2006a) using agglomerative hierarchical cluster analysis which incorporates both spatial relations and parameter value (e.g. precip amount) has been tested for verification of discontinuous fields such as precipitation. This technique was very well received at the Montreal Verification Workshop (Marzban, 2004) and has been funded by NSF for rapid transition into the DoD/NOAA/NCAR mesoscale WRF Developmental Testbed Center (DTC). A follow on paper (Marzban and Sandgathe, 2006b) has expanded this technique to allow joint clustering of forecast and observation fields to provide a better assessment of false alarms (forecasted but not observed) and misses (observed but not forecast) precipitation areas.

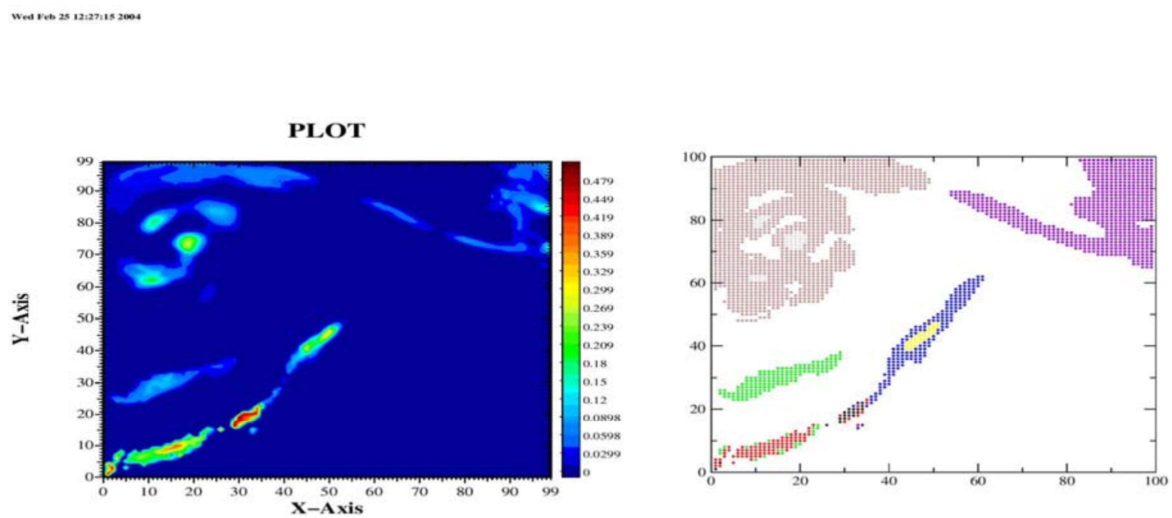

Figure 2. Example of precipitation field decomposed using agglomerative cluster analysis. [The field on the left is a plot of precipitation intensity for the NE Pacific and NW America. The field on the right is the same field indicating clustering of precipitation based on locationand intensity.]

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